

Fuel Cells

- Green Power

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For more information:
www.education.lanl.gov/resources/fuelcells

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EXHIBIT C

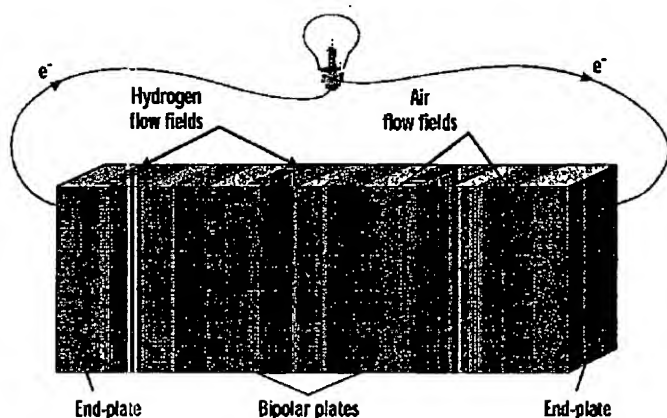
Rate of Heat Generation in an Operating Fuel Cell

Assume a 100 cm² fuel cell is operating, under typical conditions of 1 atmosphere pressure and 80°C, at 0.7 V and generating 0.6 A/cm² of current, for a total current of 60 A. The excess heat generated by this cell can be estimated as follows:

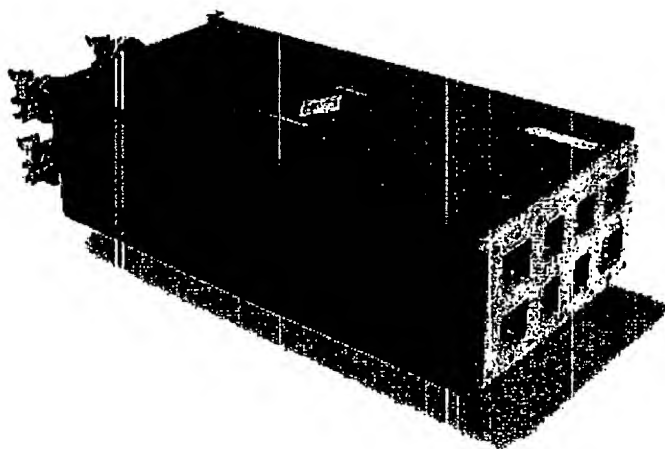
Power due to heat = Total power generated – Electrical power

$$\begin{aligned} P_{\text{heat}} &= P_{\text{total}} - P_{\text{electrical}} \\ &= (V_{\text{ideal}} \times I_{\text{cell}}) - (V_{\text{cell}} \times I_{\text{cell}}) \\ &= (V_{\text{ideal}} - V_{\text{cell}}) \times I_{\text{cell}} \\ &= (1.16 \text{ V} - 0.7 \text{ V}) \times 60 \text{ A} \\ &= 0.46 \text{ V} \times 60 \text{ coulombs/sec.} \times 60 \text{ seconds/min.} \\ &= 1650 \text{ J/min} \end{aligned}$$

This cell is generating about 1.7 kJ of excess heat every minute it operates, while generating about 2.5 kJ of electric energy per minute.



A 3 cell fuel cell stack with two bipolar plates and two end plates.



The Polymer Electrolyte Membrane Fuel Cell Stack

Since fuel cells operate at less than 100% efficiency, the voltage output of one cell is less than 1.16 volt. As most applications require much higher voltages than this, (for example, effective commercial electric motors typically operate at 200 – 300 volts), the required voltage is obtained by connecting individual fuel cells in series to form a fuel cell "stack." If fuel cells were simply lined-up next to each other, the anode and cathode current collectors would be side by side. To decrease the overall volume and weight of the stack, instead of two current collectors, only one plate is used with a flow field cut into each side of the plate. This type of plate, called a "bipolar plate," separates one cell from the next, with this single plate serving to carry hydrogen gas on one side and air on the other. It is important that the bipolar plate is made of gas-impermeable material. Otherwise the two gases would intermix, leading to direct oxidation of fuel. Without separation of the gases, electrons pass directly from the hydrogen to the oxygen and these electrons are essentially "wasted" as they cannot be routed through an external circuit to do useful electrical work. The bipolar plate must also be electronically conductive because the electrons produced at the anode on one side of the bipolar plate are conducted through the plate where they enter the cathode on the other side of the bipolar plate. Two end-plates, one at each end of the complete stack of cells, are connected via the external circuit.

In the near term, different manufacturers will provide a variety of sizes of fuel cell stacks for diverse applications. The area of a single fuel cell can vary from a few square centimeters to a thousand square centimeters. A stack can consist of a few cells to a hundred or more cells connected in series using bipolar plates. For applications that require large amounts of power, many stacks can be used in series or parallel combinations.

Polymer electrolyte membrane fuel cell stack.
(Courtesy: Energy Partners)

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